

Remarks

It is noted that the Examiner has rejected the main claims 1 and 19 under 35 USC 103(a) as unpatentable over Sieval in view of Effenberger.

The present invention is concerned with porous silicon (PSi). As the Examiner may be aware this modified form of silicon exhibits quite different properties from ordinary crystalline silicon. Although the pores extend about 30 microns into the silicon substrate, the surface of the pores has a nanostructure where quantum effects come into play. It is well known that nanostructures behave entirely differently from bulk materials. Porous silicon has a completely different behaviour from bulk crystalline silicon. Indeed the USPTO has a dedicated class, class 977, dealing with nanostructure in recognition of their unique properties. Also, class 814 refers “Group IV based elements and compounds (e.g., CxSiyGez, porous silicon, etc.)” (emphasis added), further confirming that porous silicon is a well known material and considered a separate material in its own right.

Porous silicon is created by treating crystalline silicon, such as is disclosed in the Sieval paper, by an anodic process to create pores extending into its surface in such a way that the electronic properties of the material are substantially altered. For example, porous silicon exhibits photoluminescence; ordinary crystalline silicon does not. The following is taken from the online Wikipedia encyclopedia:

Porous silicon (pSi) is a form of the chemical element silicon which has an extremely large surface to volume ratio.

It is usually manufactured by etching away most of a layer of silicon using wet chemical etches. Many etches are based on hydrofluoric acid. Electrochemical etching is also used. What is left is a fine connected network of sub micrometre silicon threads. These thin structures often have properties that are different to bulk crystalline silicon. Fine control of these etching processes enables the properties of the network to be repeatably controlled. For example, controlling the mean diameter of the threads or the pores.

One property thus changed is luminescence. Ordinarily, silicon can not be made to emit light on passage of an electric current through it (electroluminescence). Porous silicon, however, does electroluminesce at a range of wavelengths from the near infrared to the visible (blue). The wavelength depends on the thickness of the threads and on the chemical state of their surfaces. Porous silicon also emits light under illumination (photoluminescence).

In order to emphasize the fact that “porous silicon” is a term of art, its common designation in the art (PSi) and as used in the specification has also been included in independent claims 1 and 19 (see line 7, page 1).

The problem existing in the prior art was that the luminescent properties of porous silicon degrade over time. Chemical adsorbates lead to slow degradation of the photoluminescence properties of porous silicon, which restricts the use of PSi in commercial devices. Various techniques have been tried for stabilizing porous silicon to improve its longevity. For example, oxidation of the surface has been tried, but this only provides good results at red wavelengths. The object of the invention is to stabilize the porous silicon surface in such a way as to prevent or reduce this degradation effect.

The present invention depends on the discovery that passivating the surface with compounds defined in claim 1, and particularly with aldehydes, as defined in claim 2 produces good results including at the blue and green wavelengths (page 5, line 4). As noted at page 4, line 17, et seq. ageing in ambient air for several months was found to have no effect on the photoluminescent intensity. The invention thus represents an important advance in the art of the fabrication of porous silicon devices for commercial application.

The Examiner’s implication that Sieval teaches the application to porous silicon because “there is no indication … does not apply to a porous silicon surface” is analogous to asserting that a teaching pertaining for example to silicon is also a teaching to GaAs because there is no indication in the teaching that it pertains to GaAs. We are talking apples and oranges. Porous silicon and crystalline silicon are quite different materials. Moreover, the Examiner’s statement is clearly incorrect because in the section headed “Conclusions” on page 1768, Sieval describes how a silicon (100) surface is not atomically flat due to the presence of SiH groups. However, such groups only result in a departure from roughness in the order of Angstroms, i.e in the order of the distance of atomic bonds. It is clear from this statement that the author must be contemplating crystalline silicon, not porous silicon, where the depth of the pores is orders of magnitude greater than roughness measured at the atomic level.

In the case of porous silicon, the pores typically extend 30 microns or so into underlying silicon substrate. Sieval indicates that despite such “roughness” at the atomic level, stable

monolayers can nevertheless be formed, the suggestion being that the surface should ideally be flat at the atomic level, but surprisingly some "roughness" at the atomic level can be tolerated. There is a huge difference between "roughness" at the atomic level and roughness at the microscopic level, such as created in porous silicon, where the pores extend up to about 30 microns into the surface. By indicating his surprise that monolayers can be prepared *despite* the surface roughness at the atomic level, there is a strong suggestion that the author would not contemplate, and the skilled person in the art, would not be led to apply his method to a porous surface, which has a deliberately introduced roughness orders of magnitude greater than that contemplated in his paper.

If the proposed modification or combination of the prior art would change the principle of operation of the prior art invention being modified, then the teachings of the references are not sufficient to render the claims *prima facie* obvious. *In re Ratti*, 270 F.2d 810, 123 USPQ 349 (CCPA 1959)

The proposed modification of Sieval for use with porous silicon would change its principle of operation because Sieval depends on the use of atomically flat, or near flat, surfaces to produce the desired dense monolayers.

prior art reference must be considered in its entirety, i.e., as a whole, including portions that would lead away from the claimed invention. *W.L. Gore & Associates, Inc. v. Garlock, Inc.*, 721 F.2d 1540, 220 USPQ 303 (Fed. Cir. 1983), cert. denied, 469 U.S. 851 (1984)

Clearly, Sieval teaches away from the use in porous silicon in that it teaches that atomically flat surfaces are preferable. There would be no reason to apply the teachings of Sieval to porous silicon.

Sieval is an academic paper dealing with the stability of functionalized monolayers on a surface of crystalline silicon. [(100) surface or (111) surface]. The purpose of the monolayers is not clearly explained. There is a reference to "nonlinear optics" and "adsorption experiments" at the foot of the right hand column on page 1759. However, what *is* clear is that the underlying assumption in Sieval is that there is a basic need to place a monolayer on a silicon surface for some reason (for example to perform adsorption experiments) and the problem is to form a monolayer that has "thermal

stability" (see abstract). Also please see the sentence in the right hand column, page 1768: "Because of the exceptional stability of the monolayers when compared to the monolayers on gold and on silicon oxide, the protecting groups can be removed or modified, even when high temperatures are necessary. This is not the same problem as addressed by the present invention and has absolutely nothing to do with problem of "photoluminescence fatigue" addressed by the present invention.

There is no reason why one skilled in the art would consider Sieval relevant in addressing the problem at hand. The fact that Sieval's monolayers on crystalline silicon are thermally stable and allow protective groups to be removed or modified even at high temperatures would not suggest to a person skilled in the art that such monolayers could solve the photoluminescence fatigue problem outlined above or that there would be any purpose in applying Sieval's method to porous silicon. Sieval should therefore not be considered analogous art. In discussing the question of analogous art, the Federal Circuit, considering the need for a reference to be "reasonably pertinent" has stated in *In re Wood*, 202 USPQ 171, that:

[a] reference is reasonably pertinent if...it is one which, because of the matter with which it deals, logically would have commended itself to the inventor's attention in considering his problem...If a reference disclosure has the same purpose as the claimed invention, the reference relates to the same problem...[I]f it is directed to a different purpose, the inventor would accordingly have had less motivation or occasion to consider it.

Sieval teaches nothing about how to deal with the problem of photoluminescence fatigue, and is actually directed to a very different problem. Sieval does not even discuss the formation of passivating layers. Sieval clearly has a very different purpose. Sieval starts from the assumption that a monolayer is required for functionalization purposes, and the problem is how to form this monolayer on the surface so that this monolayer is things thermally stable, that is it does not decompose when subjected to heat. There is no reason why one skilled in the art addressing the problem of photoluminescence fatigue in porous silicon would find any assistance in the Sieval article, which relates to the thermal stability of monolayers on crystalline silicon, but in no way teaches that such monolayers would be useful in solving the problem noted above in porous silicon.

Clearly, then Sieval does not suggest a solution to the problem at hand. Moreover, it would make no sense for one skilled in the art to apply the disclosed monolayers in Sieval to porous silicon (PSi) based on a complete reading of Sieval. Sieval teaches the use of a crystalline surface (100) or (111). The object is to produce dense monolayers. There is some discussion in the Conclusions that despite surface roughness at the atomic level, "stable monolayers" can be prepared. Since Sieval clearly considers a slight departure from atomic flatness due to the presence of SiH groups a potential problem, but one that can be tolerated ("Despite this surface roughness dense monolayers can still be prepared" – see Conculsions), clearly one skilled in the art would not, based on this teaching, be motivated to deliberately introduce massive surface roughness at the microscopic level by introducing pores that remove the crystal surface entirely. It makes no sense, based on a complete reading of Sieval, to say that one skilled in the art would be motivated to apply its teachings to porous silicon for any reason.

The invention solves an important problem in the art, namely the stabilization of the photoluminescence properties of porous silicon, properties that are not even possessed by the crystalline silicon discussed in Sieval. This is a very surprising result that is not foreseen anywhere in the prior art and particularly not in Sieval, which does not address this problem. If the problem of photoluminescence fatigue were explained to one skilled in the art, there is absolutely no basis to suggest that such a person would be motivated to apply the teachings of Sieval to porous silicon, but even if such a basis were established "obvious to try" is not a sufficient basis to establish obviousness. See *In re Lindell*, 155 USPQ 521.

Sieval cannot therefore be considered analogous art, but even if were, there would be no motivation for one skilled in the art to turn Sieval's silicon into porous silicon because Sieval strives for an atomically flat surface to produce his desired dense monolayers. There is no suggestion in Sieval that aldehydes would penetrate pores of porous silicon or that any useful purpose would be served thereby.

The Examiner combines Effenberger with Sieval, but such combination is moot because of the clear teaching in Sieval away from the use of porous silicon. The resulting combination of Effenberger with Sieval would not result in the invention claimed, in that it would not be a method applied to porous silicon.

Furthermore the purpose of the teaching in Sieval is to provide functionalized monolayers (see title), that is monolayers that functional groups attached to them. This is exactly the opposite of what is needed with porous silicon, where the objective is not to functionalize the surface, which is already active due to its porous nature, but rather to passivate it so that it preserves its inherent luminescent properties over time.

Finally, in order to sustain a rejection under 35 USC 103, the Moreover, the prior art must teach or suggest all the claim limitations (MPEP 2143). Clearly, the prior art does not teach the application of the monolayers claimed to porous silicon, so this requirement cannot be met.

It is clear also that Effenberger is only concerned with crystalline silicon. Effenberger specifically indicates that the layers were applied to Si(111) surfaces, which are crystalline surfaces. The same also is true of Sieval, who refers to (111) surfaces, again reaffirming that he contemplates crystalline silicon surfaces, not porous silicon surfaces.

In summary, the prior art does not teach, either alone in combination, the application of the protective organic layer claimed to porous silicon, but rather teaches away from the use of porous silicon, and in particular does not teach a method of stabilizing porous silicon that results in enhanced stability of the luminescence properties. The invention represents an important contribution in the porous silicon art.

Allowance and reconsideration are therefore earnestly solicited.

Respectfully submitted,



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